

(12) UK Patent Application (18) GB (11) 2 326 269 (13) A

(43) Date of A Publication 18.12.1998

(21) Application No 9810871.5

(22) Date of Filing 20.05.1998

(30) Priority Data

(31) 9722876 (32) 10.06.1997 (33) KR

(71) Applicant(s)

Barnesung Display Devices Co. Ltd
(Incorporated in the Republic of Korea)
576 Sin-dong, Paldal-hu, Suwon-si, Kyungki-do,
Republic of Korea

(72) Inventor(s)

Jee-phil Cho
Eun-hae Kim

(74) Agent and/or Address for Service

Marks & Clerk
57-60 Lincoln's Inn Fields, LONDON, WC2A 3LS,
United Kingdom

(51) INT CL⁶

H01M 10/00

(52) UK CL (Edition P)

H1B 81040

(56) Documents Cited

EP 0301774 A US 5622792 A US 4542108 A
US 4432881 A

(59) Field of Search

UK CL (Edition P) H1B
INT CL⁶ H01M 10/00
On line databases WPI, EDOC, JAPRO

(54) Abstract Title

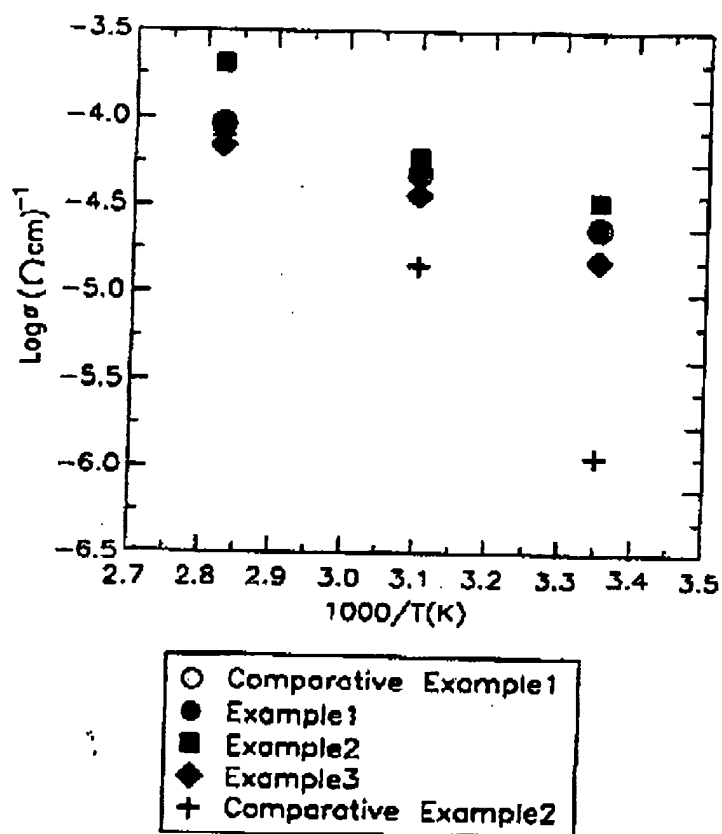
A glass-polymer composite electrolyte and a method of preparing the same

(57) A glass-polymer composite electrolyte includes a glass electrolyte having a lithium compound and at least one compound selected from B_2O_3 , P_2S_5 , SiS_2 or GeS_2 , and a polymer electrolyte.

GB 2 326 269 A

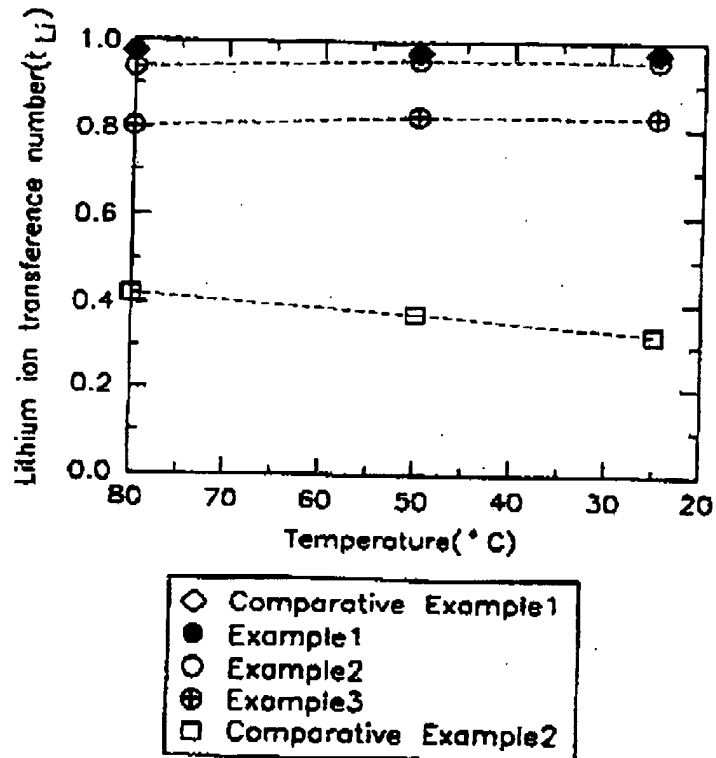
1/1

FIG. 1



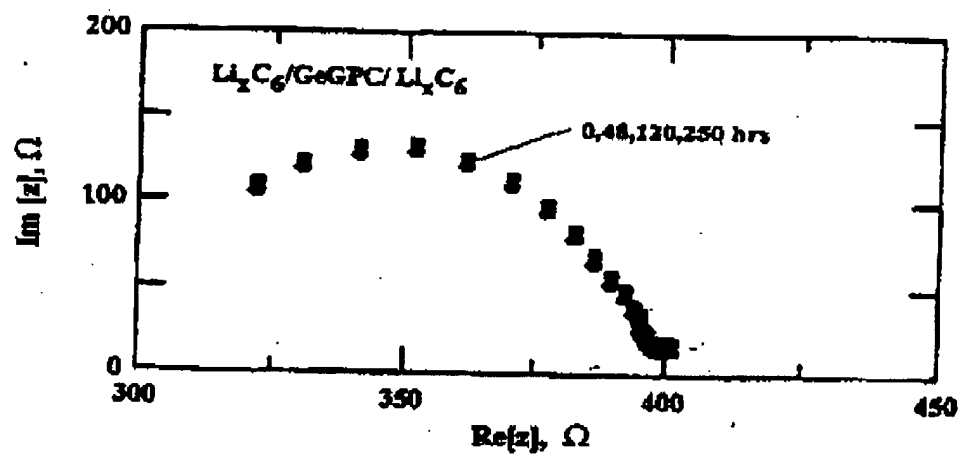
2/4

FIG. 2



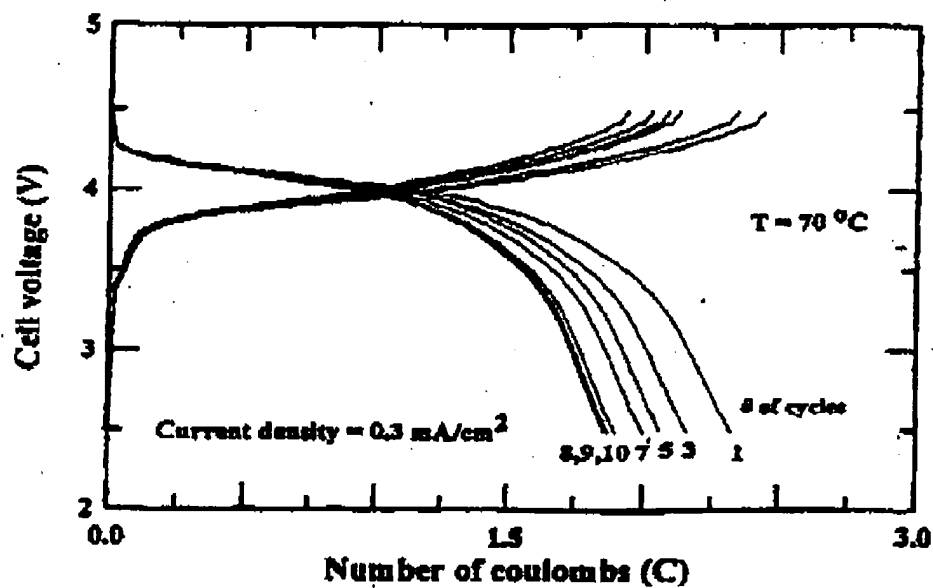
3/4

FIG. 3



2/4

FIG. 4



2326269**A GLASS-POLYMER COMPOSITE ELECTROLYTE
AND A METHOD OF PREPARING THE SAME****CROSS REFERENCE TO RELATED APPLICATION**

5 This application is based on application(s) No(s). 97-23876 filed in the Korean Industrial Property Office on June 10, 1997, the content of which is incorporated herein by reference.

BACKGROUND OF THE INVENTION

10 **(a) Field of the Invention**

This invention relates to a solid electrolyte and, more particularly, to a glass-polymer composite electrolyte which has a relatively high mechanical flexibility, ion conductivity and stability for lithium batteries.

(b) Description of the Related Art

15 Lithium is the lightest metal and has a high electronegativity. Therefore, lithium can be used to produce a cell having a large current capacity per unit of mass and high voltage. However, a lithium battery has a problem in a stability because of reactivity between the lithium metal and a liquid electrolyte. To overcome this problem, a lithium ion battery using a material
20 allowing intercalation and deintercalation of lithium ions for an anode has been developed. And a lithium polymer battery, which uses a solid polymer electrolyte instead of the liquid electrolyte, has been developed. But the solid polymer electrolyte, such as poly(ethylene oxide) and poly(propylene oxide), have a relatively low ion conductivity. The solid electrolyte is easily crystallized

at 70 - 80 °C, its ion conductivity decreases steeply.

A glass electrolyte is one of solid electrolytes for the lithium battery. It is difficult to handle because of its glass phase. It is liable to crack in charging/discharging. It can be applied to only a non-rechargeable lithium battery and not be applied to a rechargeable lithium battery.

In recent years, to overcome these problems of the polymer electrolyte and the glass electrolyte, a glass-polymer composite electrolyte consisting of B_2S_3 - Li_2S - LiI and poly(ethylene oxide)- $LiN(CF_3SO_2)_2$ has been proposed (Jaephil Cho and Meilin Liu, Georgia Institute of Technology, *Electrochimica Acta*, Vol. 42, No. 10, pp 1481-1488, 1997). But the glass-polymer composite electrolyte has a drawback in that the glass electrolyte and polymer electrolyte react each other. Furthermore, H_2O molecules in the polymer electrolyte reacts with the glass electrolyte. A method of preparing B_2S_3 is very complex. Pure B_2S_3 is difficult to prepare. B_2S_3 has a very low stability under oxygen gas atmosphere.

SUMMARY OF THE INVENTION

It is an object of the present invention to provide a glass-polymer composite electrolyte, which can be applied to rechargeable lithium batteries as well as non-rechargeable lithium batteries, is easy to handle, has a relatively high mechanical flexibility and ion conductivity, and shows no side-reaction of a glass electrolyte and a polymer electrolyte.

In order to achieve this object and others, the invention provides a glass-polymer composite electrolyte having a glass electrolyte which includes at

least one lithium compound and at least one compound selected from B_2O_3 , P_2S_5 , SiS_2 or GeS_2 , and a polymer electrolyte.

Also, the present invention provides a method of preparing a glass-polymer composite electrolyte, which comprises the steps of heating a mixture of at least one lithium compound and at least one compound selected from B_2O_3 , P_2S_5 , SiS_2 or GeS_2 at $700 \sim 900^\circ C$, forming a glass electrolyte of glassy phase by cooling the mixture, mixing the glass electrolyte and a polymer electrolyte to produce a composite electrolyte, and shaping by compressing the composite electrolyte at $80 \sim 110^\circ C$.

BRIEF DESCRIPTION OF THE DRAWING

A more complete appreciation of the invention, and many of the attendant advantages thereof, will be readily apparent as the same becomes better understood by reference to the following detailed description when considered in conjunction with the accompanying drawings, wherein:

Fig. 1 is a graph showing the ion conductivities of glass-polymer composite electrolytes according to embodiments of the present invention;

Fig 2. is a graph showing a lithium ion transference number of a glass-polymer composite electrolyte according to embodiments of the present invention;

Fig 3. is a graph showing an interfacial stability between a glass-polymer composite electrolyte according to embodiments of the present invention and $LiCoO_2$ at $70^\circ C$; and

Fig 4. is a graph showing charge/discharge curves of a cell with a glass-polymer composite electrolyte according to an embodiment of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

5 The first aspect of the present invention is a glass-polymer composite electrolyte having a glass electrolyte which includes at least one lithium compound and at least one compound selected from B_2O_3 , P_2S_5 , SiS_2 or GeS_2 , and a polymer electrolyte.

GeS_2 is the most preferable compound as one element of the glass-polymer composite electrolyte. Preferably, the lithium compound is at least one element selected from Li_2S , Li , Li_2O , Li_2SO_4 , $LiBr$ or $LiCl$. Preferably, the glass electrolyte is GeS_2-Li_2S-LiI . Preferably, the molar ratio of the $GeS_2 : Li_2S : LiI$ in the GeS_2-Li_2S-LiI is 0.3~0.45 : 0.1~0.3 : 0~0.25. Preferably, the polymer electrolyte includes a lithium salt and at least one polymer selected
10 from poly(ethylene oxide), poly(propylene oxide), poly(vinylidene fluoride) or poly(acrylonitrile). Preferably, the lithium salt is at least one compound selected from $LiClO_4$, $LiCF_3SO_3$, $LiAsF_6$, $LiPF_6$, $LiN(CF_3SO_2)_2$, $LiBr$ or lithium acetate.
15

Preferably, the volume ratio of the glass electrolyte:polymer electrolyte
20 in the glass-polymer composite electrolyte is 75:25~93:7. When the polymer electrolyte is more than 25 vol%, the ion conductivity of the glass-polymer composite electrolyte becomes lower.

The second aspect of the present invention is a method of preparing a

glass-polymer composite electrolyte, which comprises the steps of heating a mixture of at least one lithium compound and at least one compound selected from B_2O_3 , P_2S_5 , SiS_2 or GeS_2 at $700 - 900^\circ C$, forming a glass electrolyte of glassy phase by cooling the mixture, mixing the glass electrolyte and a polymer electrolyte to produce a composite electrolyte, and shaping by compressing the composite electrolyte at $60 - 110^\circ C$.

Preferably, the heating step is carried out under vacuum, nitrogen gas or noble gas such as argon. Preferably, the glass electrolyte used in the mixing step is powder type. It is preferable that the shaping step is carried out at $70 - 90^\circ C$ for 1-3 hr. The time of the shaping step can be changed depend on the quantity of the composite electrolyte.

Also, the present invention provides a battery using the glass-polymer composite electrolyte. Preferably, the battery is a lithium ion battery. The battery can use a graphite or an amorphous carbon for an anode material and $LiMn_2O_4$, $LiCoO_2$ or other lithium metal oxide compound for a cathode material. According to the conventional method of preparing a lithium ion battery, those skilled in the art can make a lithium ion battery using the glass-polymer composite electrolyte of the present invention.

Example 1

Appropriate amounts of germanium (99.99%, ESPI Co. Ltd.) and sulfur (99.99%, Alfa Co. Ltd.) were mixed and the mixture was then transferred to a silica tube. The tube was vacuumed and baked at $900^\circ C$ for 12 hrs. Then, the tube was cooled in air and glassy GeS_2 was obtained. The GeS_2 5.7g, LiI

(99.99%, Alfa Co. Ltd.) 1.3g and Li_2S (99.9%, Cerac Co. Ltd.) 3g were mixed. The mixture was transferred to a quartz tube. The quartz tube was baked at 800°C for 15 mins under vacuum and cooled in a liquid nitrogen. A glass electrolyte of $0.45\text{GeS}_2\text{-}0.3\text{Li}_2\text{S-}0.25\text{LiI}$ was obtained.

5 A polymer electrolyte was prepared by dry ball milling poly(ethylene oxide) [PEO] and $\text{LiN}(\text{CF}_3\text{SO}_2)_2$ in the ratio of 8:1.

The prepared glass electrolyte and polymer electrolyte were mixed in the volume ratio of 93:7. The mixture was put in a die having a diameter of 13 mm and shaped by compressing gradually in the pressure of 1-3 ton/cm² at 80°C for 2 hrs. A glass-polymer composite electrolyte consisting of
10 93vol% $[0.45\text{GeS}_2\text{-}0.3\text{Li}_2\text{S-}0.25\text{LiI}]$ and 7vol% $[\text{PEO-LiN}(\text{CF}_3\text{SO}_2)_2]$ was obtained.

Example 2

A glass electrolyte was prepared according to Example 1.

A polymer electrolyte was prepared according to Example 1.

15 The prepared glass electrolyte and polymer electrolyte were mixed in the volume ratio of 87:13. The mixture was put in a die having a diameter of 13 mm and shaped by compressing gradually in the pressure of 1-3 ton/cm² at 80°C for 2 hrs. A glass-polymer composite electrolyte consisting of
87vol% $[0.45\text{GeS}_2\text{-}0.3\text{Li}_2\text{S-}0.25\text{LiI}]$ and 13vol% $[\text{PEO-LiN}(\text{CF}_3\text{SO}_2)_2]$ was
20 obtained.

Example 3

A glass electrolyte was prepared according to Example 1.

A polymer electrolyte was prepared according to Example 1.

The prepared glass electrolyte and polymer electrolyte were mixed in the volume ratio of 75:25. The mixture was put in a die having a diameter of 13 mm and shaped by compressing gradually in the pressure of 1~3 ton/cm² at 80 °C for 2 hrs. A glass-polymer composite electrolyte consisting of 75vol% $[0.45\text{GaS}_2\text{-}0.3\text{Li}_2\text{S-}0.25\text{LiI}]$ and 25vol% $[\text{PEO-LiN}(\text{CF}_3\text{SO}_2)_2]$ was obtained.

Example 4

Boron hydroxide was melted by baking at 1000 °C for 4~5 hrs. B_2O_3 was prepared by quenching it. The B_2O_3 4.3g, LiI (99.99%, Alfa Co. Ltd.) 1.3g and Li_2O (99.9%, Cerac Co. Ltd.) 4.5g were mixed. The mixture was transferred to a quartz tube. The quartz tube was baked at 800 °C for 15 mins under vacuum and cooled in a liquid nitrogen. A glass electrolyte of $0.45\text{B}_2\text{O}_3\text{-}0.3\text{Li}_2\text{O-}0.25\text{LiI}$ was obtained.

A polymer electrolyte was prepared by dry ball milling PEO and $\text{LiN}(\text{CF}_3\text{SO}_2)_2$ in the ratio of 8:1.

The prepared glass electrolyte and polymer electrolyte were mixed in volume the ratio of 87:13. The mixture was put in a die having a diameter of 13 mm and shaped by compressing gradually in the pressure of 1~3 ton/cm² at 80 °C for 2 hrs. A glass-polymer composite electrolyte consisting of 87vol% $[0.45\text{B}_2\text{O}_3\text{-}0.3\text{Li}_2\text{O-}0.25\text{LiI}]$ and 13vol% $[\text{PEO-LiN}(\text{CF}_3\text{SO}_2)_2]$ was obtained.

Example 5

P_2S_5 6.8g, LiI (99.99%, Alfa Co. Ltd.) 2.2g and Li_2S (99.9%, Cerac Co. Ltd.) 1g were mixed. The mixture was transferred to a quartz tube. The quartz tube was baked at 800 °C for 15 mins under vacuum and cooled in a liquid nitrogen. A glass electrolyte of $0.45P_2S_5-0.3Li_2S-0.25LiI$ was obtained.

A polymer electrolyte was prepared by dry ball milling PEO and $LiN(CF_3SO_2)_2$ in the ratio of 8:1.

The prepared glass electrolyte and polymer electrolyte were mixed in the volume ratio of 87:13. The mixture was put in a die having a diameter of 13 mm and shaped by compressing gradually in the pressure of 1-3 ton/cm² at 80 °C for 2hrs. A glass-polymer composite electrolyte consisting of 87vol% [$0.45P_2S_5-0.3Li_2S-0.25LiI$] and 13vol% [$PEO-LiN(CF_3SO_2)_2$] was obtained.

Example 6

Silicon and sulfur were mixed in the molar ratio of 1:2. The mixture was reacted at 800 °C for 1 week in a quartz tube under vacuum. SiS_2 was obtained by breaking the quartz tube.

SiS_2 4.7g, LiI (99.99%, Alfa Co. Ltd.) 1.6g and Li_2S (99.9%, Cerac Co. Ltd.) 3.7g were mixed. The mixture was transferred to a quartz tube. The quartz tube was baked at 800 °C for 15 mins under vacuum and cooled in a liquid nitrogen. A glass electrolyte of $0.45SiS_2-0.3Li_2S-0.25LiI$ was obtained.

A polymer electrolyte was prepared by dry ball milling PEO and $LiN(CF_3SO_2)_2$ in the ratio of 8:1.

The prepared glass electrolyte and polymer electrolyte were mixed in the volume ratio of 87:13. The mixture was put in a die having a diameter of 13 mm and shaped by compressing gradually in the pressure of 1-3 ton/cm² at 80 °C for 2 hrs. A glass-polymer composite electrolyte consisting of
5 87vol% $[0.45\text{SiS}_2-0.3\text{Li}_2\text{S}-0.25\text{LiI}]$ and 13vol% $[\text{PEO-LiN}(\text{CF}_3\text{SO}_2)_2]$ was obtained.

Comparative Example 1

GeS_2 5.7g, LiI (99.99%, Alfa Co. Ltd.) 1.3g and Li_2S (99.9%, Cerac Co. Ltd.) 3g were mixed. The mixture was transferred to a quartz tube. The quartz tube was baked at 800 °C for 15 mins under vacuum and cooled in a
10 liquid nitrogen. A glass electrolyte of $0.45\text{GeS}_2-0.3\text{Li}_2\text{S}-0.25\text{LiI}$ was obtained.

Comparative Example 2

A polymer electrolyte was prepared by dry ball milling PEO and $\text{LiN}(\text{CF}_3\text{SO}_2)_2$ in the ratio of 8:1.

Comparative Example 3

15 Boron 0.76g and sulfur (99.99%, Alfa Co. Ltd.) 3.24g were mixed and the mixture was then transferred to a carbon-coated silica tube. The tube was vacuumed and sealed. The tube was baked at 900 °C for 12 hrs. The tube was cooled in air. Glassy B_2S_3 was obtained. B_2S_3 5.3g, LiI (99.99%, Alfa Co. Ltd.) 3.3g and Li_2S (99.9%, Cerac Co. Ltd.) 1.4g were mixed. The mixture was
20 transferred to a quartz tube. The quartz tube was baked at 800 °C for 15 mins under vacuum and cooled in a liquid nitrogen. A glass electrolyte of $0.45\text{B}_2\text{S}_3-0.3\text{Li}_2\text{S}-0.25\text{LiI}$ was obtained.

A polymer electrolyte was prepared by dry ball milling PEO and $\text{LiN}(\text{CF}_3\text{SO}_2)_2$ in the ratio of 8:1.

The prepared glass electrolyte and polymer electrolyte were mixed in the volume ratio of 87:13. The mixture was put in a die having a diameter of 13 mm and shaped by compressing gradually in the pressure of 1~3 ton/cm² at 80 °C for 2 hrs. A glass-polymer composite electrolyte consisting of 87vol% $[\text{0.45B}_2\text{S}_3\text{-0.3Li}_2\text{S-0.25LiI}]$ and 13vol% $[\text{PEO-LiN}(\text{CF}_3\text{SO}_2)_2]$ was obtained.

※ Preparation of a lithium ion battery ※

LiMn_2O_4 was prepared by baking LiNO_3 and MnO_2 at 800 °C for 30 hrs.

A cathode material was made of LiMn_2O_4 , the glass-polymer composite electrolyte of Example 2 and acetylene carbon black in the weight ratio of 50:40:10.

An anode material was made of a petroleum coke and the glass-polymer composite electrolyte of Example 2 in the weight ratio of 60:40.

The weight ratio of the LiMn_2O_4 and the petroleum coke was 1:2.

The powdered cathode material and powdered anode material were dispersed beneath and on the glass-polymer composite electrolyte of Example 2 and shaped by compressing at 80 °C.

A lithium ion coin cell was prepared by sandwiching the glass-polymer composite electrolyte between a composite LiMn_2O_4 electrode and a composite carbon electrode. The thickness of the coin cell was 150 ~ 200 μm and its open cell voltage before being charging at 70 °C was 0.1V. The cell was

cycled between 2.5V and 4.5V (Fig. 4). The initial capacity was 2.36C and a capacity after 10 cycles of charging/discharging was 1.87C.

The electrolyte ion conductivities of Example 1, Example 2, Example 3, Comparative Example 1 and Comparative Example 2 were determined by the AC and DC measurements method (Fig 1). The ion conductivity of the Example 2 was $4.5 \times 10^{-5}(\text{cm} \cdot \Omega)^{-1}$ at room temperature and $2 \times 10^{-4}(\text{cm} \cdot \Omega)^{-1}$ at 80 °C.

Fig. 2 shows the lithium ion transference numbers (t_L) of the electrolytes of Example 1, Example 2, Example 3, Comparative Example 1 and Comparative Example 2. As shown Fig. 2, the t_L of Example 1 and Example 2 at 80 °C were about 1 but the t_L of Comparative Example 2 was 0.4. Therefore, these glass-polymer composite electrolytes of Example 1 and Example 2 can use about 100% of the total lithium ion in charging/discharging, but the electrolyte of Comparative Example 2 can use about 40% of total lithium ion in charging/discharging.

Since the polymer electrolyte is easily crystallized at 70~80 °C, the ion conductivity and the lithium ion transference number becomes lower at 70~80 °C. However, the glass-polymer composite electrolyte of the present invention have a relatively high ion conductivity at 70~80 °C. Therefore, it can be used for a long time at 70~80 °C.

The cell of $\text{Li}_7\text{C}_6/\text{glass-polymer composite electrolyte}$ consisting of 93vol% $[\text{0.45GeS}_2\text{-0.3Li}_2\text{S-0.25LiI}]$ and 7vol% $[\text{PEO-LiN}(\text{CF}_3\text{SO}_2)_2]$ / Li_7C_6 were

prepared. The stability of the glass-polymer composite electrolyte against Li_xC_6 was determined at 70 °C (Fig. 3). The change of the interfacial resistance between Li_xC_6 and the glass-polymer composite electrolyte according to time was negligible. Therefore, the chemical stability of the glass-polymer composite electrolyte and Li_xC_6 was good.

Compared to the glass electrolyte, the glass-polymer composite electrolyte have a relatively high packing density since the pores between the glass particles are filled with the polymer.

While the present invention has been described in detail with reference to the preferred embodiments, those skilled in the art will appreciate that various modifications and substitutions can be made thereto without departing from the spirit and scope of the present invention as set forth in the appended claims.

13

12

M&C Folio: 230P78993

Document #: 266502

WHAT IS CLAIMED IS:

1. A glass-polymer composite electrolyte comprising:
a glass electrolyte which includes at least one lithium compound and at least one compound selected from the group consisting of B_2O_3 , P_2S_5 , SiS_2 and GeS_2 ; and
a polymer electrolyte.
2. The glass-polymer composite electrolyte of claim 1 wherein the compound is GeS_2 .
3. The glass-polymer composite electrolyte of claim 1 or claim 2 wherein the lithium compound is at least one element selected from the group consisting of Li_2S , LiI , Li_2O , Li_2SO_4 , $LiBr$ and $LiCl$.
4. The glass-polymer composite electrolyte of any one of claims 1 to 3 wherein the glass electrolyte is GeS_2 - Li_2S - LiI .
5. The glass-polymer composite electrolyte of claim 4 wherein the molar ratio of the GeS_2 : Li_2S : LiI is 0.3-0.45 : 0.1-0.3 : 0-0.25.
6. The glass-polymer composite electrolyte of any one of claims 1 to 5 wherein the polymer electrolyte comprises a lithium salt and at least one polymer selected from the group consisting of poly(ethylene oxide), poly(propylene oxide), poly(vinylidene fluoride) and poly(acrylonitrile).
7. The glass-polymer composite electrolyte of claim 6 wherein the lithium salt is at least one compound selected from the group consisting of $LiClO_4$, $LiCF_3SO_3$, $LiAsF_6$, $LiPF_6$, $LiN(CF_3SO_2)_2$, $LiBr$ and lithium acetate.

8. The glass-polymer composite electrolyte of any one of claims 1 to 7 wherein the volume ratio of the glass electrolyte : polymer electrolyte is 75:25-93:7.
9. A battery formed using a glass-polymer composite electrolyte of any one of claims 1 to 8.
10. A method of preparing a glass-polymer composite electrolyte, the method comprising the steps of:
 - heating a mixture of at least one lithium compound and at least one compound selected from the group consisting of B_2O_3 , P_2S_5 , SiS_2 and GeS_2 at $700 \sim 900^\circ C$;
 - forming a glass electrolyte by cooling the mixture;
 - mixing the glass electrolyte and a polymer electrolyte to produce a composite electrolyte; and
 - shaping by compressing the composite electrolyte at $60 \sim 100^\circ C$.
11. The method of claim 10 wherein the compound is GeS_2 .
12. The method of claim 10 or claim 11 wherein the glass electrolyte is GeS_2-Li_2S-LiI .
13. The method of preparing a glass-polymer composite electrolyte of claim 12 wherein the molar ratio of the $GeS_2 : Li_2S : LiI$ is $0.3-0.45 : 0.1-0.3 : 0-0.25$.
14. A glass-polymer composite electrolyte substantially as described herein with reference to Examples 1 to 6.
15. A method of preparing a glass-polymer composite electrolyte substantially as described herein with reference to Examples 1 to 6.

8. The glass-polymer composite electrolyte of any one of claims 1 to 7 wherein the volume ratio of the glass electrolyte : polymer electrolyte is 75:25~93:7.
9. A battery formed using a glass-polymer composite electrolyte of any one of claims 1 to 8.
10. A method of preparing a glass-polymer composite electrolyte, the method comprising the steps of:
 - heating a mixture of at least one lithium compound and at least one compound selected from the group consisting of B_2O_3 , P_2S_5 , SiS_2 and GeS_2 at $700 \sim 900^\circ C$;
 - forming a glass electrolyte by cooling the mixture;
 - mixing the glass electrolyte and a polymer electrolyte to produce a composite electrolyte; and
 - shaping by compressing the composite electrolyte at $60 \sim 110^\circ C$.
11. The method of claim 10 wherein the compound is GeS_2 .
12. The method of claim 10 or claim 11 wherein the glass electrolyte is GeS_2-Li_2S-LiI .
13. The method of preparing a glass-polymer composite electrolyte of claim 12 wherein the molar ratio of the $GeS_2 : Li_2S : LiI$ is $0.3 \sim 0.45 : 0.1 \sim 0.3 : 0 \sim 0.25$.
14. A glass-polymer composite electrolyte substantially as described herein with reference to Examples 1 to 6.
15. A method of preparing a glass-polymer composite electrolyte substantially as described herein with reference to Examples 1 to 6.



Canadian
Office

16

Application No: GB 9810871.5
Claims searched:

Examiner: A.R. Martin
Date of search: 26 June 1998

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.P): H1B

Int Cl (Ed.6): H01M 6/00, 10/00

Other: On line databases WPI, EDOC, JAPIO

Documents considered to be relevant:

Category	Identity of document and relevant passage	Relevant to claims
A	EP 0301774 A UKAEA see claim 6	Claims 1 and 10 at least
A	US 5622792 A Hydro-Quebec see claim 1	"
A	US 4542108 A US Dept. of Energy see claim 1	"
A	US 4432891 A " " " see claim 1	"

X	Documents indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Documents indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
E	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.

An Executive Agency of the Department of Trade and Industry